ADROIT V1: Design of Low-cost Modular Educational Robot Platform

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Abstract

Educational robotics becomes a creative way to use technology to implement solutions based on our wit and skills, and not just become a consumer of technology. The field of educational robotics is growing and consequently a number of educational robot kits have been developed within the last decade. But many of complete set of educational robot are still expensive, or the cheaper one usually lack of features such as modularity. This paper proposes a design of a low-cost educational robotics module with a modular design in mind. Modularity is one of the key concepts developed in educational robotics. This makes the students understand the function and working principle of each robot part more easily. Modularity also gives the students the flexibility in combining and creating a robotics design to explore their creativity within the given project. The overall parts can be categorized into three main building block; mechanical building block, electronics building block and programming building block.

Keywords: Education robot, robot kits, modularity, building block.

1. Introduction

New technologies have a big impact in the way modern societies live. In a similar way, the education of children in schools has been directly influenced by new technologies. The use of these technological tools in schools can improve the quality of education and help to prepare students to a technological society. During the last decade, educational robotics has attracted the high interest of teachers and researchers as a valuable tool to develop cognitive and social skills for students from elementary school to high school and to support learning in science, mathematics, technology, informatics and other school subjects or interdisciplinary learning activities [1,2]. Many studies have been conducted in the investigation in the field of educational robotics and identification of the new challenges and trends focusing on the use of robotic technologies as a tool that will support creativity and other learning skills this last decade. Through robotics, Learners are invited to work on experiments or problem-solving with selective use of available resources, according to their own interests, search and learning strategies. Learners could build something on their own, preferably a tangible object, that they can both touch and find meaningful. They seek solutions to real world problems, based on a technological framework meant to engage the curiosity and initiate motivation [3].

Robotics has been gaining attention from students in every educational level from elementary school up to higher education. This phenomenon is indicated by number of participants in many robotics competitions had been held in Indonesia. But this situation still limited to some degree of experience, because the lack of availability of a low-cost educational modular designed robotics kit. Thus, not all of students can explore their creativity at maximum. This paper proposes a design a low-cost educational mobile robot module that designed in a modular form. The proposed educational robot is divided into three main parts; mechanical building block, electronics building block and programming building block. Each block consists of several modules that can be constructed and combined with others to complete a robot building block. This modularity is intended to make the students to understand the function and working principle of each part more easily. Modularity also can foster the student's creativity by giving them a flexibility in combining and creating a robotics design to explore their idea and imagination within the given project.

2. Related Works

Educational robotics is a learning environment in which the students are motivated by the design and construction of creations. It is an excellent tool to explore, identify and develop the technological talent of all children and youth [4]. It seeks the student's adaptation through processes in order to learn science and technology topics. Educational Robotics aims to arouse the students' interest on traditional subjects that are mainly related with technology. Robotics in Education (RiE) has been proposed since the 80s and has been successfully implemented by several schools worldwide. Seymour Papert with his pioneer LEGO/LOGO project is considered a precursor of several works involving RiE [5]. Following the project, started in 1987, the LEGO Robot Design Competition (M.I.T. course number "6.270") which developed by Professor W. Flowers has inspired a course on industrial design. This course has become as a student-organized programming contest [6]. This course gives students a kit of identical parts at the beginning of the term, and the specifications of a competitive task to build a remote-controlled machine that would solve that task faster and better than the other students' machines. The approach of pedagogical also rooted from the constructionist theories of learning developed by Seymour Papert [7]. Another activity in the field of educational robotics aiming in the training of future and in-service teachers in the effective introduction and use of robotics in school classes has been conducted under TERECoP project (Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods) [8]. This project involves 8 educational institutions from 6 European countries.

The use of standardized robotics kits which consists of sets of hardware pieces and tools becomes most pedagogical methodologies for RiE [9]. Some the educational those robots are; GoGo Board [10], Topobo [11], LEGO [12], and VEX [13]. GoGo Board has library of open source electronic devices that support multiple use. But it does not provide a specific pedagogical methodology. Topobo is a robotic toy consisting of building blocks where some components have kinetic memory, which can record a sequence of movements from an initial hand-moved example. LEGO has is an educational assembly kit composed o static and moving parts. The electronic components are composed by sensors, motors and the NXT programmable microcontroller, which support three motors and up to four sensors. Lego also become one of the most popular robotics kits, and is accompanied by a suggested pedagogical methodology. VEX provides software, hardware and classroom resources bundles for construction of advanced robotics systems.

Robotics kits mentioned above are already available in the market. But most of them are still relatively expensive, especially for the complete set modules [14-16]. We emphasize that low buying-power should not impede schools from implementing technological education projects. So to make RiE more accessible, more affordable kits should be existed. This paper proposes a cheaper alternative educational robotics module compared to those products in regards to the given features. The main features of the proposed design are its modularity and expand ability. User can create their self made module to be combined with the main module. This feature should help more advanced user to explore more deep idea, understanding and challenge, especially in electronics and programming parts.

3. Proposed Modular Design

The proposed educational robotics module can be categorized as three main parts; mechanical building block, electronics building block and programming building block, as depicted in Figure 1.

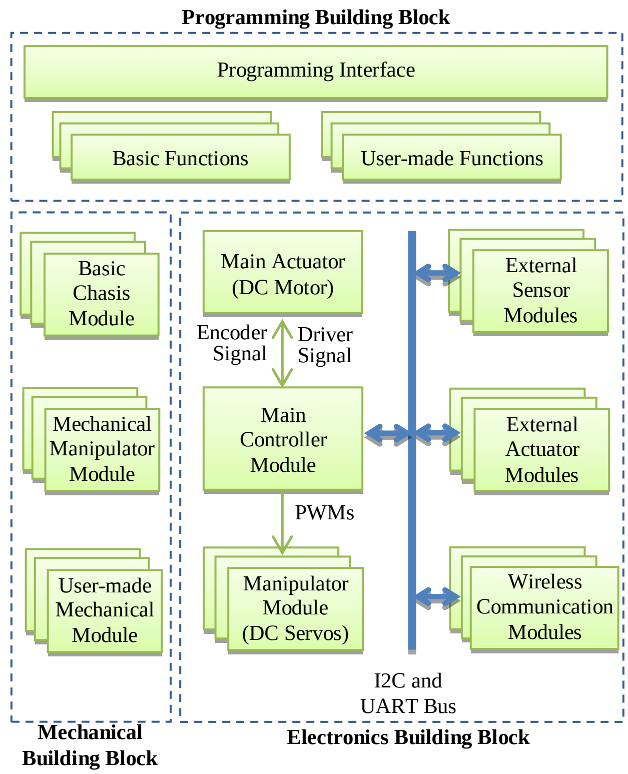


Figure 1. ADROIT V1 Building Blocks

3.1. Programming Building Block

The programming module consists of programming interface and function blocks. The program source in each function is open. Users can modify each function or add their own function. The programming process is done in PC via text-based programming interface or via graphical user interface (GUI). Using GUI, user can program the robot by constructing function blocks from the graphical menu. Figure 2 shows the developed programming GUI for ADROIT V1. But the GUI in programming interface is still in its early development stage. Thus, for more advanced user, text interface using on C language programming is still more recommended. After the program is built, user can download the program to the robot's controller via In System Programing ISP (ISP).

Function blocks in ADROIT V1 can be categorized as sensor interface, actuator interface, communication interface, and controller function block. Sensor interface consists of functions to access sensor developed in ADROIT V1, such as; IMU sensor, AHRS sensor, line sensor, and encoder sensor. Actuator interface consists of function to access the actuator in ADROIT V1, such as main DC motor and servo motors. Communication interface consist of function to access external peripherals from the main controller via UART and I2C. Controller function block consists of functions to setup the controller board, to control the program flow, and to control the robot movement.

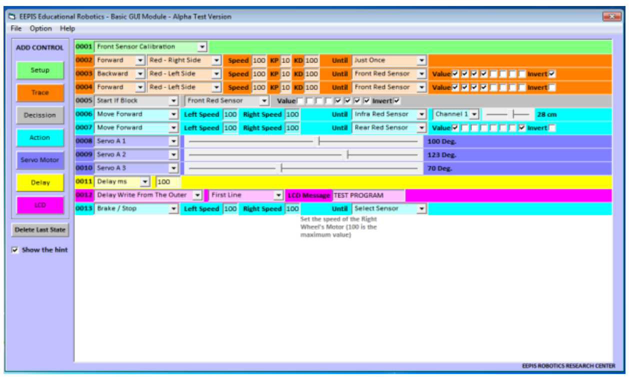


Figure 2. GUI for ADROIT V1 programming

3.2. Mechanical Building Block

The mechanical building block consists of basic chassis module, optional gripper module and additional user made module. Chassis module which is shown in the Figure 3 is the main part of this building block.

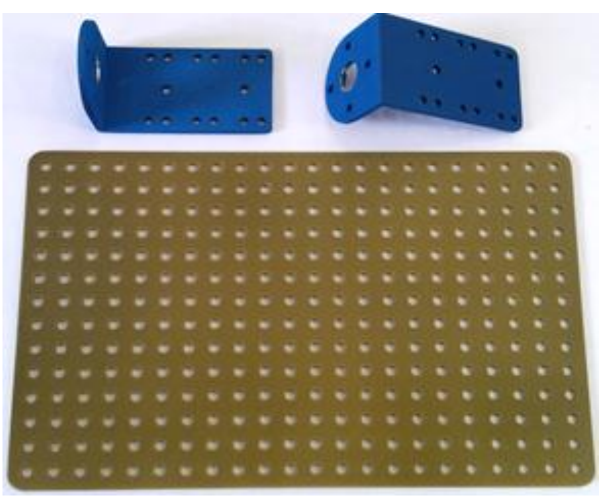


Figure 3. Main chassis module in ADROIT V1

The main component in this module us a matrix of M3 sized holes with 7 mm pitch made from FR4 PCB. User can attach other mechanical modules or the electronic modules within this matrix of holes using bolt and nut or PCB spacer.

3.3. Electronics Building Block

The electronics building block consists of main controller, sensor, and actuator modules. Electronic modules in this building block are supplied from the main controller module from the battery power source. All schematics are supplied within each electronic module. This makes a chance to the user to have a deep understanding to the underlying process and possibility to modify or create their own electronic module.

3.3.1. Main Controller

Main controller module is the heart of the ADROIT V1, as depicted in Figure 4. It will control other modules in the robot. Main controller module has its internal sensors and actuator interfaces. Main controller also equipped with internal voltage regulators for 5 volt and 3.3 volt. This regulator will supply other external electronic modules. Main controller also can be connected to the external modules, such as, sensor, actuator and communication modules. Communication to the external modules can be connected via I2C and UART bus. These bus are multi-drop enabled, thus many modules can be connected to the same bus, up to 63 modules in each bus. ADROIT V1 communication protocol is open and relatively simple to implement.

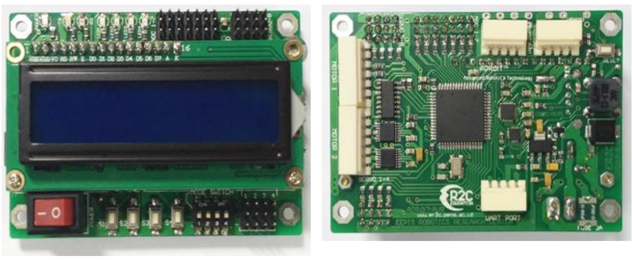
The detail specifications and features of the main controller are:

- ❖ Dimension : 85 mm x 57mm
- ❖ Main Processor : AVR ATMega128
- ❖ Input Output (I/O)
    - Servo Connector : 8 channels (with 5V supply voltage)
    - ADC Input : 7 channels (with 5V supply voltage)
    - General I/O : up to 15 channels (shared with ADC andServo)
    - Mode Switch : 4 Pins (Dipswitch)
    - Push Button : 4 channels + Reset Switch
- ❖ Communication Port
    - 2 channel UART : Up to 115200bps (1 channel is shared with ISP port)
    - 1 channel I2C : Up to 400KHz
    - 1 ISP Connector
- ❖ On board Sensor
    - Accelerometer : 3 Axis (MPU 6050)
    - Gyroscope : 3 Axis (MPU 6050)
    - Magnetometer : 3 Axis (HMC5883L)
- ❖ On board DC Motor Driver
    - Dual Motor Driver : Up to 3 Ampere
    - Speed Controllable : Via PWM (up to 20 KHz)
    - Integrated dual encoder interface (each channel)
- ❖ Power supply
    - Input Voltage : 7.2 Volt (2 cells Battery)
    - 5V Regulator : Up to 5 Ampere (TD7590)

- 3.3V Regulator : Up to 1 Ampere (L1117-3.3)
- Power Switch : 3 Ampere, Rocker Switch
- Fuse : 5 Ampere (resettable)

❖ Accessories
- On board LCD : LCD character 16x2 with switchable backlight
- Buzzer : Frequency controllable

❖ On board LED
- 4 general purposes
- 2 UART Indicator : Tx and Rx
- 1 power Indicator



a. Top View **b.** Bottom View

Figure 2. Main Controller Board

3.3.2. Sensor Modules

Sensor Modules in ADROIT V1 are divided into two categories, internal and external sensor modules. The internal sensors are available from the controller main module, such as; 3 axis accelerometer, 3 axis gyroscope, 4 axis magnetic compasses and battery level monitor. External sensor module can be connected to the main controller module via I2C and UART bus. Some sensor modules also can be connected to main controller module via its internal ADC interface. Figure 5 shows one of sensor module in ADROIT V1 starter kit which is connected to main controller via UART.

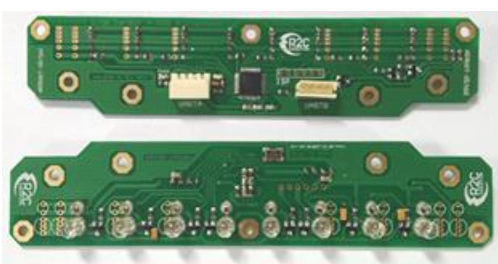


Figure 5. RGB Line Sensor Module

3.3.3. Actuator Modules

Actuator module in ADROIT V1 can be divided in to two categories; internal and external actuator modules. Internal actuator modules in the main controller consist of dual DC motor drivers and PWM generator for servo motors. The external actuator modules are additional modules that can be connected to the main controller via I2C and UART bus. Figure 6 shows available actuator modules in ADROIT V1 starter kit.

a. DC Motors **b.** Servo Motors

Figure 6. Actuator Module

3.3.4. Communication Module

Communication module is an optional module that enables the main controller to communicate with other device wirelessly. The module is connected to the main controller via I2C bus. The available wireless communication module in ADROIT V1 is infrared or Bluetooth interface as shown in Figure 7. Using this module, main controller can send and receive data with other device, such as PC for tele-monitoring and tele-controlling purposes. User can also use this module to connect with the supporting joystick to give a control command to the the robot.

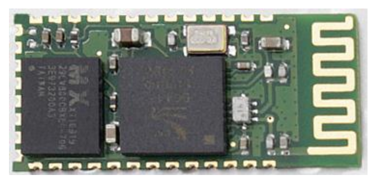


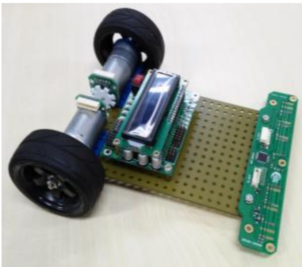
Figure 7. Bluetooth Communication Module

4. Robot Design

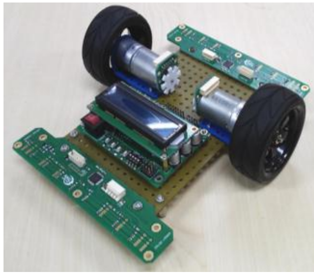
As an educational robot kit, ADROIT V1 can be useful enough to teach the user about electronics, mechanical design and its programming counterpart. It can be designed based on the given problem and the user idea. Because of its modularity, there will be plenty of combinations of modules that may happen. Even with a same given problem, user may end up with a different final design. This makes the users has a possibility to foster their creativity on how they look the problem and how to solve it efficiently.

4.1. Construction

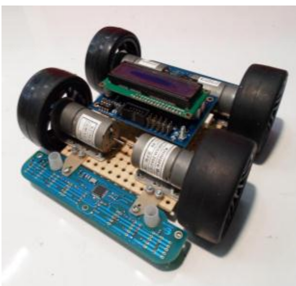
The modularity of the ADROIT V1 enables the robot kits to be constructed in to several models as depicted in Figure 8. The holes matrix in the main mechanical chassis is the one key to make the construction of other component become more flexible. The electronic parts and mechanical parts have been designed to align with the multiple distance of each hole in the main chassis. In order to create the desired robot model, each component such as; actuator, sensor and other mechanical module can be attached in the holes by using PCB spacer or by using bolts and nuts. Some models that can be constructed from ADROIT V1 are line follower robot (Figure 8. a, b and c), sumo robot (Figure 8.d.), transporter robot (Figure 8.e. and f.), legged robot (Figure 8.g.), and balancing robot (Figure 8.h.).



a. Line Follower Robot

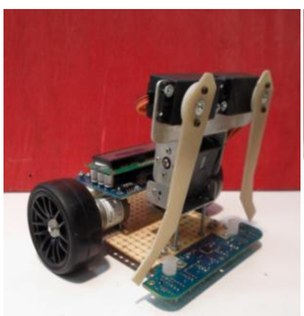


b. Double Sensors Line Follower



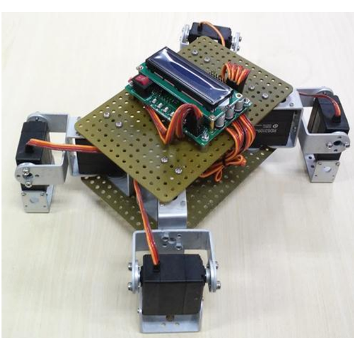
c. Four Wheels Line Follower

d. Sumo Robot

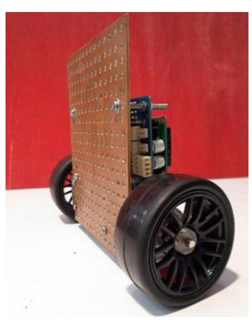


e. Single Gripper Transporter

f. Double Grippers Transporter



g. Legged Robot



h. Balancing Robot

Figure 8. Reference Designs

Each of those models can be modified even further by the user. The modules arrangement can be modified and other modules can be added on to it. For example, user can combine line follower robot ability with balancing robot design and become a balancing line follower robot as depicted in Figure 9.

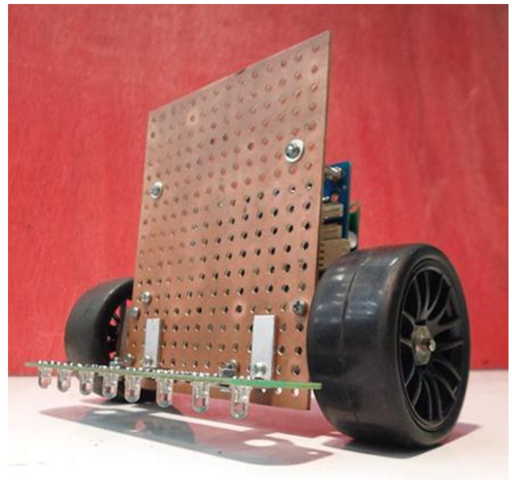


Figure 9. Line Follower Balancing Robot

4.2. Control Mode

Another benefit of the ADROIT V1 modular building block is enabling a flexible method to control the robot movement. Robot can be programmed to move using manual, automatic, or semi-automatic control mode. In manual control mode, the movement is controlled by the operator by using a joystick that connected to the robot via Infra Red or Bluetooth interface. One example of this mode is when the robot as a mobile robot which movements including direction and speed are controlled using the joystick.

In automatic control mode, the robot is programed to move based on the given scenario by using its sensor data reading. The simplest example of this mode is when the robot is designed as a line tracer that moves based on the line sensor data. In semi-automatic mode, robot can process special task automatically using its sensor data, and still can be commanded by the user using joystick. The example of this mode is when the robot is designed as a remotely balancing robot. The automatic control part handles the balancing process by using its IMU sensor, and the robot movement is controlled manually by operator using the joystick.

5. Conclusion

ADROIT V1 is an alternative design of robotic kit that can be used for Robotics in Education program. This robotic kit is designed in modular form, thus it can be assembled and constructed by user. It enables the user to combine the modules not only limited to the reference designs. There are still plenty other possibilities of the robot design based on the combination of used modules, mechanical construction, robot model, and the control mode. The communication protocol in the programming building block is relatively simple and open. The schematic of each module in the electronics building block is also open. These features enable the user to modify and even make their own module to be combined with the already available modules. Unfortunately, the GUI programming building block in ADROIT V1 is still in the early development stage, thus more convenient user programming interface needs to be developed as one of our future works.

6. Acknowledgement

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